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MEMORANDUM FOR PRS (In-House/Contractor Publication)

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SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-2002-214**
Drew DeGeorge (PRS) et al., "Integrated High Payoff Rocket Propulsion Technology Program and Tactical Missile Propulsion" (Paper/Oral Presentation/VuGraphs)

55713

Research Technology Agency, NATO **(Statement A)**
(Denmark, 23-27 September 2002) (<u>Deadline: ASAP, per Dr. Kessel</u>)

The Integrated High Payoff Rocket Propulsion Technology Program And Tactical Missile Propulsion Status

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SUMMARY

The Integrated High Payoff Rocket Propulsion Technology Program (IHPRPT) is a structured Government (DoD with NASA) and Industry program to improve U.S. rocket boost and orbit transfer, spacecraft and tactical propulsion systems. The program is technology driven, goal oriented, and application focused. Integration of the technologies developed by the IHPRPT program is accomplished through key demonstrations. These demonstrators are used to verify compliance with goals. The achievement of the IHPRPT goals and the transition to operational systems provide significant payoff as well as a high return on investment.

The IHPRPT program is being conducted as a fully coordinated, but not joint, effort. Each agency and Department of Defense component is responsible for funding and managing their respective portions of the effort. The effort is headed by the IHPRPT Steering Committee, which has representatives from each participating agency and service.

Industry plays an active role in the program through an involvement in planning, participation at Steering Committee meetings, conducting of technology programs, identification of transition opportunities, advocacy of the program, and teaming.

Tactical propulsion is one of the three major application areas. Technologies are being pursued for air, ground, surface and gun launched applications. Component and propulsion system demonstrators are planned for achieving IHPRPT Phase II and III goals. The Phase I air-launched demonstrator was completed successfully. The payoff of transitioning tactical propulsion technologies into the field after completion of any of the three IHPRPT phases is significant.

Transitioning technology from IHPRPT has begun in all application areas.

INTRODUCTION

The IHPRPT program initiated its program execution phase in 1996 to focus and coordinate rocket propulsion technology development and demonstration within the Department of Defense (DoD), NASA, and rocket propulsion industry. The program vision is to double U.S. rocket propulsion capability (cost and performance) by 2010. Government and industry worked together to develop *firm, challenging*, but *attainable* propulsion technology goals that are *time-phased* and *measurable*. Attainment of the goals and subsequent incorporation of technologies into existing and future systems will enable the U.S. to reduce launch costs and improve performance and reliability[i] in boost and orbit transfer, spacecraft and tactical missile systems.

With this common vision established for boost and orbit transfer, spacecraft, and tactical propulsion, both government and industry directed their resources toward the pursuit of these goals. The stability of IHPRPT funding from the government and clear goals encouraged industry to align their technology development plans with IHPRPT and invest their independent research and development (IR&D) pursuing the goals.

This paper will describe the IHPRPT program, goals and the payoffs for each of the mission application areas related to space, and discuss some of the key transition opportunities for the technologies. The IHPRPT program structure and processes will also be described along with a more detailed description of the tactical propulsion portion of the program.

GOALS

The IHPRPT goals for Boost and Orbit Transfer and Spacecraft propulsion are shown in Table 1. The goals are measured relative to 1993 baseline technology. The goals represent percentage improvements over these documented baselines. Baseline systems have been identified for each class of propulsion system being pursued. Baselines do not necessarily represent the specific production systems if the state-of-the-art was deemed to be significantly more advanced than a previously fielded system and could be adequately modeled in a propulsion system.

The configuration of a given demonstration is determined by scale and cost. For a given solid propulsion company it will be more cost effective for them to propose using a large scale motor they produce themselves. Similarly, liquid engine or component test article scale may be selected based on existing hardware or tooling applicable and beneficial. Whatever configuration is selected the key is to develop, integrate and demonstrate technologies satisfying the goals in comparison to the previously specified baselines. Since actual costs are highly competition sensitive the government accepts a given contractors estimate of the baseline costs of a system representing the baseline propulsion system.

These goals represent a coordinated commitment and vision to the United States Government and industry for the investment of its resources. The level of coordination, planning, joint funding and program execution has set IHPRPT apart as a model program for science and technology development. Pursuit of these specific goals were agreed to based on the significance of the payoffs achievable if transitioned to operational systems.

Table 1. IHPRPT Goals for Boost and Orbit Transfer and Spacecraft Propulsion

Boost and Orbit Transfer Propulsion	**2000**	**2005**	**2010**
Reduce Stage Failure Rate	25%	50%	75%
Improve Mass Fraction (Solids)	15%	25%	35%
Improve Isp (Solids)	2%	4%	8%
Improve Isp (sec) (Liquids)	14	21	26
Reduce Hardware Cost	15%	25%	35%
Reduce Support Costs	15%	25%	35%
Improve Thrust to Weight (Liquids)	30%	60%	100%
Mean Time Between Removal (Mission Life: Reusable)	20	40	100
Spacecraft Propulsion			
Improve I_{stot}/M_{wet} (Electrostatic/Electromagnetic)	20%/200%	35%/500%	75%/1250%
Improve I_{sp} (Bipropellant/Solar Thermal)	5%/10%	10%/15%	20%/20%
Improve Density: I_{sp} (Monopropellant)	30%	50%	70%
Improve Mass Fraction (Solar Thermal)	15%	25%	35%

BOOST, ORBIT TRANSFER AND SPACECRAFT PROPULISON PAYOFFS

The nominal approach for evaluating payoffs of propulsion technology goal achievement is by modeling the levels of improvement in potential systems and then simulating their use in operational scenarios. Payoffs can be shown in various ways. A set of quantitative payoffs has been generated for each application and for each phase of the program Payoffs from meeting the IHPRPT goals for Boost and Orbit transfer are shown in Figure 1. IHPRPT tactical propulsion payoffs will be discussed later in this paper. IHPRPT payoffs can take a variety of forms such as reducing the hardware and support costs while simultaneously increasing the payload capability. In another form, these technologies would allow reducing the size of the propulsion system for the same payload. In the case of Boost and Orbit Transfer payoffs, shown in Figure 1, there is a cost benefit of 33% (both hardware and support costs are included). For the same size vehicle there is a payload capability. increase with expendable launch vehicles (ELVs) of 22%. These two factors work together to lower the cost per pound of payload to orbit by more than 50% (more payload for less cost).

Furthermore, for a "clean sheet" design, a smaller launch vehicle can be used that incorporates IHPRPT technology to deliver the same size payload. A smaller launch vehicle will have correspondingly lower costs for hardware and support.

The payoffs for spacecraft propulsion are shown in Figure 2. In this case, the payoffs are singular in nature. Either the life of a satellite is extended 45%, satellite payload is increased 30%, or the repositioning capability is increased 500%. It is estimated that the cost savings associated with these payoffs is $240M over the life of a satellite.

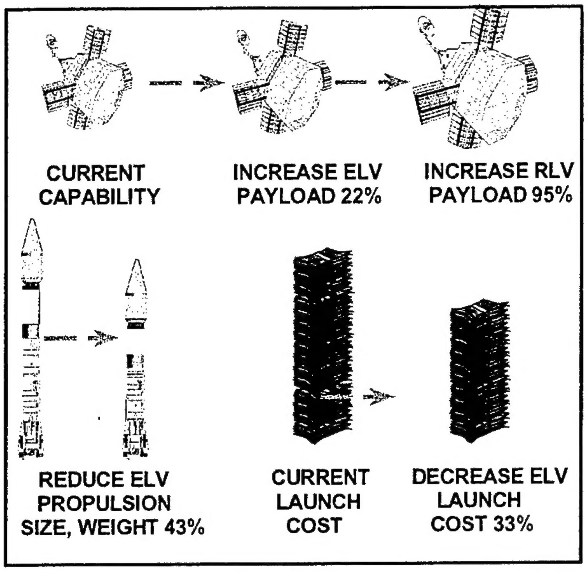


Figure 1. IHPRPT Boost and Orbit Transfer Payoff

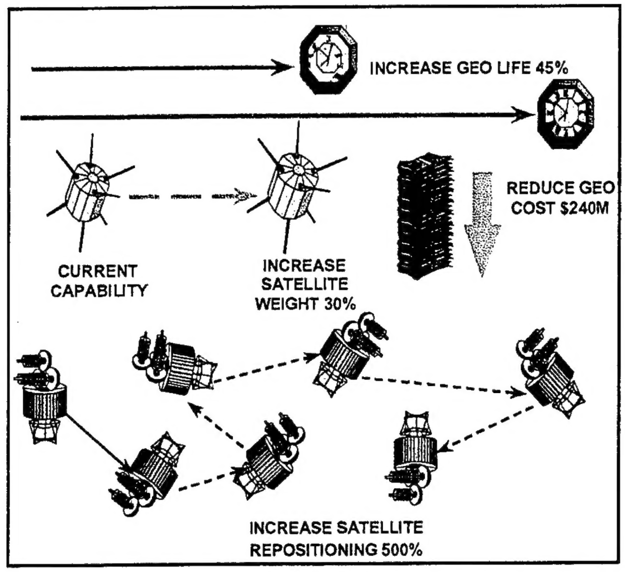


Figure 2. IHPRPT Spacecraft Propulsion Payoff

IHPRPT PROGRAM APPROACH, ORGANIZATION AND MANAGEMENT[ii]

The IHPRPT program is organized into three *mission application areas* with demonstrators defined in each area:

- Boost and Orbit Transfer
- Spacecraft
- Tactical

Within each of the above mission application areas there are five *technology areas*: Propellants, Propellant Management Devices, Combustion and Energy Conversion Devices, Controls, and Demonstrators.

- The Propellant area includes solids (including bond liner), liquids, hybrids, catalysts and gels.
- The Propellant Management Device (PMD) area includes insulated cases, small tanks, feed systems, bladders, turbomachinery, thermal protection systems, and pressurization systems.
- The Combustion and Energy Conversion Device (C&ECD) area includes nozzles, gas generators, preburners, injectors, igniters, and combustion chambers.
- The controls area includes actuators, controllers, ordnance devices, valves, and health monitoring systems.
- The Demonstrator area addresses component technology integration and scale-up issues. This test, or set of tests, is used to accumulate data for comparison to the baselines. With this comparison, quantified progress toward goal achievement is determined.

Materials development is treated as a separate but integral part of the program. Whether it is propellants or structural materials we are often technology limited. Energetic materials for propellants is conducted through our propellant development teams. Within the program we have a separate team called the IHPRPT Materials Working Group (IMWG) to develop advanced structural materials and manufacturing processes. This sub-team is led by the Air Force Materials Laboratory and NASA Marshall Space Flight Center. With additional DoD, NASA and industry membership this team has developed and conducts a materials program supporting component technology objective and goal achievement supporting all three application areas.

Specific *technical objectives* are developed for each of the supporting technology areas to guide individual projects. The technical objectives are targets (such as component weight reduction, density increase in propellant, etc.) that each supporting technology must meet in order to achieve the overall IHPRPT goals for that mission application area. The objectives must cumulatively result in a quantified improvement in the state of the art by necessarily satisfying the goals. This must be achieved by the accomplishment of specific technology projects, and must have a specific date by which it will be met.

From the technical objectives, *technical challenges* are identified. A technical challenge, in IHPRPT terminology, answers the question, "Why can't we accomplish the objective today?" Technical challenges are the most fundamental, scientific problem that must be overcome to meet the objective.

Once goals, technical objectives, and technical challenges have been identified, the *approach* is developed to overcome the technical challenges in order to meet the objectives to reasonably ensure goal achievement if successful.

The IHPRPT program uses an approach referred to as the GOTCHA (Goals, Objectives, Technical Challenges, and Approach) process to develop and communicate the projects that will enable goal achievement. The GOTCHA process documents the necessary and sufficient technology programs needed to satisfy goal achievement serving to maintain program focus over time.

DEMONSTRATORS AND TRANSITION OPPORTUNITIES

Demonstrator projects which are planned, under way, or have been completed in Boost and Orbit Transfer and Spacecraft propulsion in the following areas:

Boost and Orbit Transfer

- Cryogenic Boost: both primary and upper stage propulsion
- Solid Boost: both Boost and Orbit Transfer Stages
- Hydrocarbon Boost

Spacecraft

- Solar Thermal Propulsion
- Electric Propulsion
    - Hall Thruster
    - Pulsed Plasma Thrusters
    - Ion
    - Monopropellant
    - Bi-propellant

Tactical (smokey, reduced smoke and minimum smoke)

- Solid
- Hybrid
- Gel

Transition opportunities include Evolved Expendable Launch Vehicle (EELV) upgrades, Reusable Solid Rocket Motor (RSRM) upgrades for the space shuttle, small launch vehicles (Athena, Taurus, Air Launch, etc.), Reusable Launch Vehicles (RLVs), Solar Orbit Transfer Vehicle, strtategic systems and various other

military and commercial spacecraft. The tactical propulsion technologies are being considered for upgrades to existing systems as well as for new systems.

THE STEERING COMMITTEE

The IHPRPT Steering Committee, whose members represent each participating agency and service, heads the program organizational structure. This committee is co-chaired by the Office of the Undersecretary of Defense staff specialist for Space and a NASA Headquarters representative. This committee meets bi-annually as a group and provides guidance to the five technology planning groups and three application areas. These planning groups are composed of senior science/engineering specialists from each participating agency and service, and are continually engaged in maintaining and updating detailed government long-range plans.

Each of the propulsion companies participating in the IHPRPT program has also developed, and maintains, its own long-range company plan and business strategy to achieve the goals of the program. These company plans are updated regularly, and formally coordinated with the government participants at least bi-annually.

The most important task for the management of the IHPRPT program has been to establish a dedicated and farsighted technical community across government and industry in order to provide an environment in which full coordination and long-range planning, technology execution, and accountability can be realized. This environment is being provided through the Steering Committee meetings. The meetings are structured and scheduled to provide reporting on key elements of the program on a timely basis. The meetings include participation by both government and industry. The committee is also responsible for establishing relationships with other federal agency performing related and/or supportive technologies.

THE IHPRPT PROCESS INTEGRATES WITH LONG-RANGE PLANS

As discussed previously, the IHPRPT program began by establishing baselines and goals relative to those baselines. Based on the goals, conceptual propulsion system designs for each class of demonstrator and phase were developed with allocated requirements for all the necessary components. These component requirements are termed technical objectives within each component technology area (Propellant, PMD, C&ECD, Controls). Technical approaches are developed and programs are conducted to meet the objectives. Once met these technologies are appropriate to integrate into demonstrators. Demonstrators are defined and tested that show compliance with the goals. Once demonstrated, the technology is available to the user community. Figure 3 shows how the process integrates planning activities for space launch with DoD, NASA, and industry. The planning process is continuous. Figure 4 shows a summary of the major components of the IHPRPT approach.

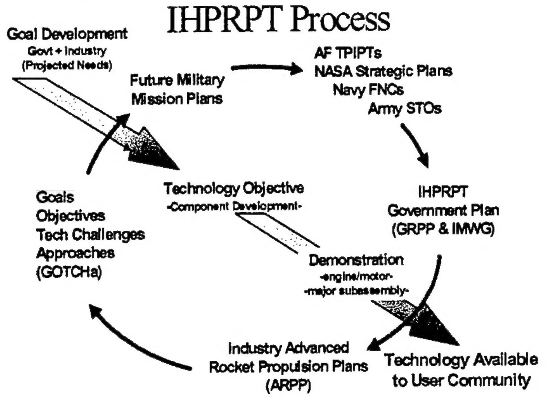
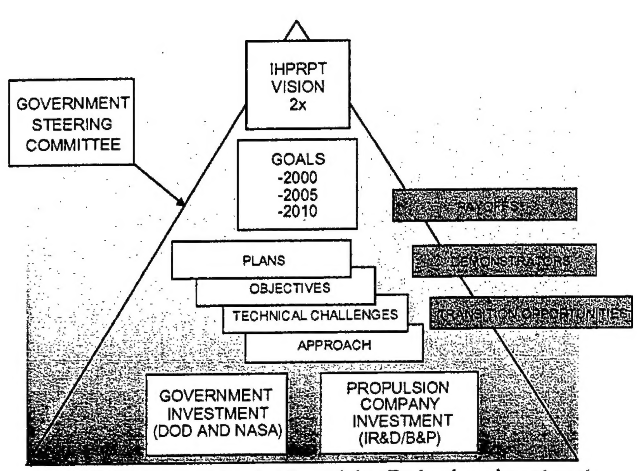


Figure 3. IHPRPT Process



Basis for Government Rocket Propulsion Technology Investment

Figure 4. The IHPRPT Components

The industry will be updating its their Advanced Rocket Propulsion Plans (ARPPs) again soon. These plans circulate and are briefed to various DoD and NASA parties involved in the planning process. There is significant interaction between IHPRPT planning and government users (DoD and NASA planning processes). This interaction feeds the creation of the IHRPT Government Rocket Propulsion Plan (GRPP), DoD Planning Documents, NASA Center Implementation Plans, and Industry Long-Range Plans. These plans are then checked for consistency with the ARPP, and the process continues.

Overlaid on this continuous planning process is the conduct of IHPRPT component technology programs and demonstrators. The success that each of these programs has towards meeting the goals outlined in the ARPP influences the planning process as well.

INDUSTRY PARTICIPATION

A cornerstone of the success of IHPRPT is its coordination with industry. The industry/government partnership that created and maintains IHPRPT requires that each partner actively participate. It has been noted that companies (and government agencies) all benefit from investment in IHPRPT commensurate with the effort expended on the program. The following are some of the key activities that industry should be doing to ensure the IHPRPT program's success.

INDUSTRY PLANNING

All propulsion contractors participating in IHPRPT must have an approved ARPP. Specialty companies that do not work all aspects of a mission application area, but have valuable contributions to offer (e.g., a motor case or nozzle material researcher), must have their ideas integrated with a propulsion company and participate in their ARPP. These ARPPs are the contractors' plans to meet the time-phased goals of each mission application area they are working in. A contractor need not work all three mission application areas but must work all applicable goals relating to a propulsion system class (this does not mean each component technology project must work all goals). The major aspects of an ARPP (in descending order of priority) are:

- Complete description of how meeting the goals will be demonstrated (including test method, data acquisition, data analysis , etc.)
- Company's long range business strategy to achieve these goals (e.g., make or buy)
- Plans for collaboration or teaming, as necessary, to meet all goals in the application areas being worked
- Complete description of the projects needed to develop the technology base that will be demonstrated
- Detailed roadmap showing the technology development/demonstration pathway
- Estimation of the funds required for each project and the anticipated company investment.
- List of milestones for each project (more than one/year for current or near-term projects)
- Full explanation of the technical challenges that must be overcome, and how that will be accomplished (GOTHCA Charts)
- Critical path analysis with an explanation of the current status along that path
- Payoff analysis describing the system level payoffs expected by attainment of the technologies being demonstrated
- Identification of potential military, civil and commercial transition targets

The GRPP is a combination of industry ARPP inputs and government in-house technologies. It is the government's overarching plan designed to prioritize projects, establish critical paths, provide the most logical set of projects needed to achieve the goals with minimum risk and cost.

INDUSTRY STEERING COMMITTEE PARTICIPATION

Each company designates a primary IHPRPT representative that attends Steering Committee meetings, performs on action items, and organizes and coordinates briefings at the meeting and ARPP reviews. The

Steering Committee meetings include an industry caucus/debrief session. Each company representative actively participates in the caucus to bring to light areas of concern as well as to point out areas where development is progressing well.

Traditionally, industry has sponsored the Summer Steering Committee meeting. This obligation is rotated between participating companies.

INDUSTRY IDENTIFYING TRANSITION OPPORTUNITIES

Industry provides additional value to the program by helping to identify component and complete propulsion system technology transition opportunities. With the expansion of the commercial market and increased reliance on commercial vehicles for government payloads, synergy with commercial vehicles is essential to ensure high return on investment.

INDUSTRY TEAMING

Teaming between IHPRPT participants is highly encouraged by the government. There are several ways that industry should consider teaming:

- Team with another propulsion company: Teaming between propulsion companies leverages technology investment and can build complementary teams where each company conducts technology development in their area of strength. This is especially true on demonstrator projects where there is quite often only one demonstrator and it is unusual for one contractor to have all of the component technologies in hand to demonstrate the goals. Furthermore, involving more than one propulsion company also increases transition opportunity.
- Team with suppliers: Material and component suppliers often have the best understanding of improvements possible with their products. Bringing them onto a propulsion company team increases the chances for meeting the goals and for transitioning the technology.
- Team with government laboratory: Significant in-house research and development is conducted at the laboratories under IHPRPT and other funding. Government in-house work should be supported in company ARPPs. Teaming with government laboratories ensures that the technology development is considering transition of their technology to industry. Cooperative Research and Development Agreements (CRADAs), Space Act Agreements (with NASA), and Technology Investment Agreements (TIAs) are all vehicles with which to team with the government.

GOVERNMENT AND INDUSTRY TECHNOLOGY FUNDING

IHPRPT was founded as a government/industry partnership and as such, industry has an obligation to fund technology development through IR&D. Figure 5 shows the nominal split of DoD, NASA, and Industry funds. In order for funds to be counted as IHPRPT funds, they must be directed at IHPRPT goals and be included in the ARPP roadmap for a demonstrator.

In addition to allocating company resources to pursue IHPRPT goals, industry also conducts contracted technology programs. The government procures IHPRPT programs through various contractual instruments (Program Research and Development Announcement (PRDA), Broad Area Announcements (BAA), NASA Research Announcements (NRA), and Requests for Proposal (RFP) to name a few). Companies respond with proposals. IHPRPT has been instrumental in implementing significant changes to the procurement process to streamline proposal evaluation and reduce cost to the contractors.

During the conduct of the IHPRPT technology programs, progress toward the technical objectives is constantly monitored. Meeting the IHPRPT technical objectives is an important measure of program success.

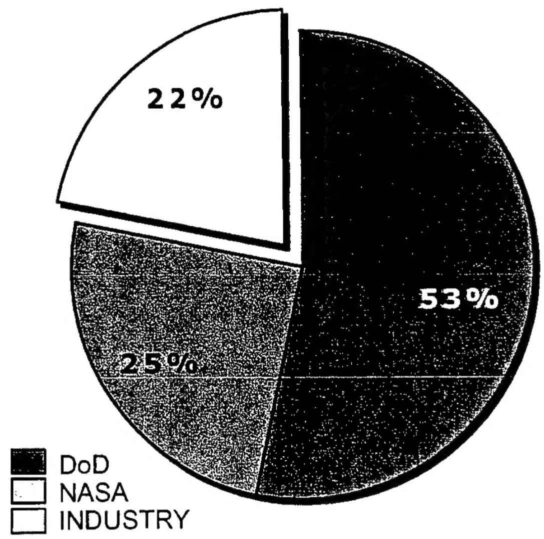


Figure 5. Funding Sources for IHPRPT

TACTICAL PROPULSION PORTION OF THE IHPRPT PROGRAM

Tactical propulsion is one of the three major application areas of the IHPRPT program. The focus of the tactical technology program is to significantly increase propulsion system delivered energy and increase mass fraction. These technology improvements are pursued while keeping in mind applicability to envisioned potential operational system, acquisition cost in a production program and the potential to satisfy insensitive munitions requirements. Any and all propulsion system configurations and propellant combinations of interest can be evaluated and developed if desired.

The IHPRPT tactical propulsion system goals (Table 2) for the three phases are delivered energy increases of 3%, 7% and 15% with mass fraction improvements of 2%(10%), 5%(20%) and 10%(30%) without (with) thrust vector control (TVC) or thrust magnitude control (TMC). These goals were selected based on the potential payoffs in various tactical missions and although challenging they were also viewed as being achievable

Factors considered when developing or evaluating a technology for applicability into an operational system include weight, volume and other weapon platform integration constraints in addition to effectiveness in operational simulations.

Cost of propulsion in a tactical system, as in all systems is difficult to accurately model. This is especially true considering many of the materials and propellant ingredients have not been used in any production system. In lieu of this we use engineering experience with factors historically driving cost to assess a trend of the costs using the technologies being developed. The target for tactical propulsion is to try to maintain the cost of the propulsion system for the various applications.

Insensitive munitions response is driven considerably by final propulsion system design and are initially assessed based on historical contributors. The final evaluation for IM compliance will need to be done in the final full scale propulsion system designs.

PERFORMANCE	2000	2005	2010
Increased Delivered Energy	+3%	+7%	+15%
• Smoke			
• Reduced Smoke			
• Minimum Smoke			
Increased Mass Fraction			
• Motor without TVC/TMC	+2%	+5%	+10%
• Motor with TVC/TMC	+10%	+20%	+30%
SAFETY			
Meet Safety Requirements as Performance Goals are Met			
COST			
No Increase in Cost as Performance Goals Are Met			

Table 2. IHPRPT Tactical Propulsion Goals

TACTICAL PROPULSION PAYOFFS AND APPROACHES

In order to quantify the level of payoff of achieving the IHPRPT tactical goals and integrating the technology into operational systems detailed modeling and simulation is conducted. In addition to direct one-to-one kinematic performance comparisons with existing systems, payoffs are also assessed in the context of dual role missiles and the impact of changing the size of a missile holding required performance constant. As you would expect the specific payoff varies with mission, missile design and the level of technology modeled. The technology being developed is applicable to air, ground and surface launched missile systems. Detailed technology development and demonstration plans have been constructed built using the GOTChA process through Phase III

The approaches being pursued to achieve the goals for the various applications include advancements in propellant, nozzle, case, thrust vector and thrust magnitude control.

New high energy ingredients and propellants are being developed with an expanded range of ballistic properties. High burn rate and high operating pressure propellants with increased mechanical properties are desired to increase specific impulse and mass fraction.

With these increases in propellant and motor operating characteristics the nozzle operating environment becomes more severe. New composite matrix and monolithic refractory material systems and manufacturing processes are being developed to survive the more severe environment.

Increased strength to weight case material systems are being pursued for high pressure operation with minimum thickness. The marerials being considered here are metal matrix and organic matrix composites.

Mission flexibility is driven by the ability to manage thrust. There are many ways to manage thrust. The approaches being pursued in this area include developing lightweight/low volume, durable thrust vector and thrust magnitude control devices. These two methods in combination can yield a high degree of missile maneuverability making a dual role missile more viable to consider.

Depending on the mission and how the technology is integrated the payoffs of achieving IHPRPT Phase III goals can be as much as doubling flyout range (Figure 6.), significant decreases in time-to-targtet, 30% decrease in missile size or saving hundreds of millions of dollars in acquisition and logistics costs.

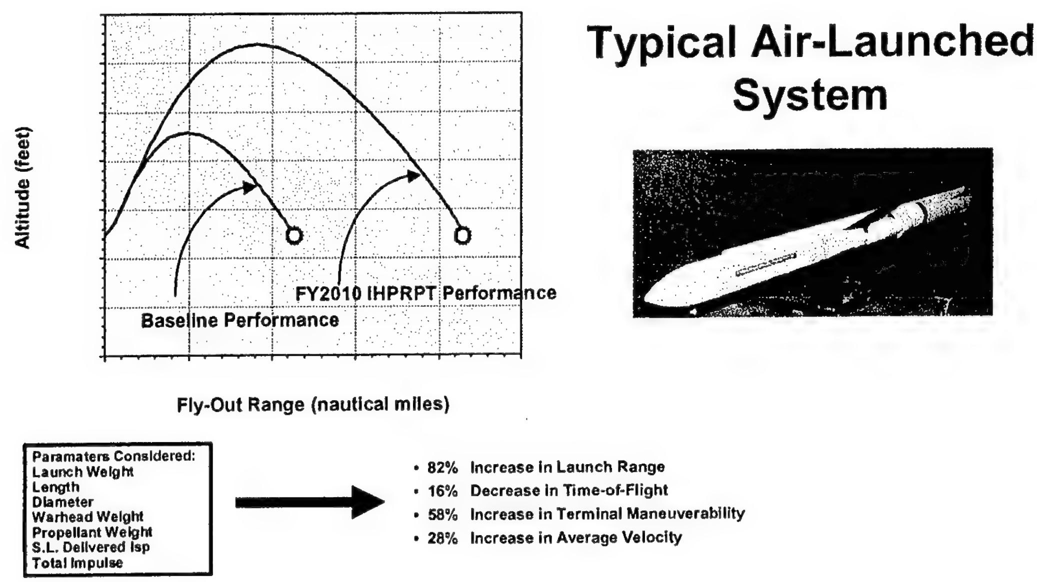


Figure 6. Example IHPRPT Payoff Analysis Results

SUMMARY AND CONCLUSIONS

The IHPRPT program is a highly coordinated U.S. DoD, NASA and industry effort focusing technology to double rocket propulsion capability by 2010 for space and missile applications. The rigorous process is designed to be challenging for all participants, maximizing military, civil, and commercial rocket propulsion payoffs.

This model research and development program leverages technology investments from all the U.S. participants in rocket propulsion technology development. Goal-oriented, application and transition opportunity focused, the national technology program enabling new and low-cost space access, on-orbit missions and drastically improved tactical missile capability is IHPRPT.

Notes and References:

[i] Summarized and excerpted from a draft copy of "Point Paper, Intergrated High Payoff Rocket Propulsion Technology," Dr. Robert C. Corely, Air Force Research Laboratory

Integrated High Payoff Rocket Propulsion Technology

Partners in Rocket Propulsion Technology Development

Outline

- Program Summary
- Goals and Objectives
- Process
- Payoffs
- Tactical Program
- Summary and Conclusion

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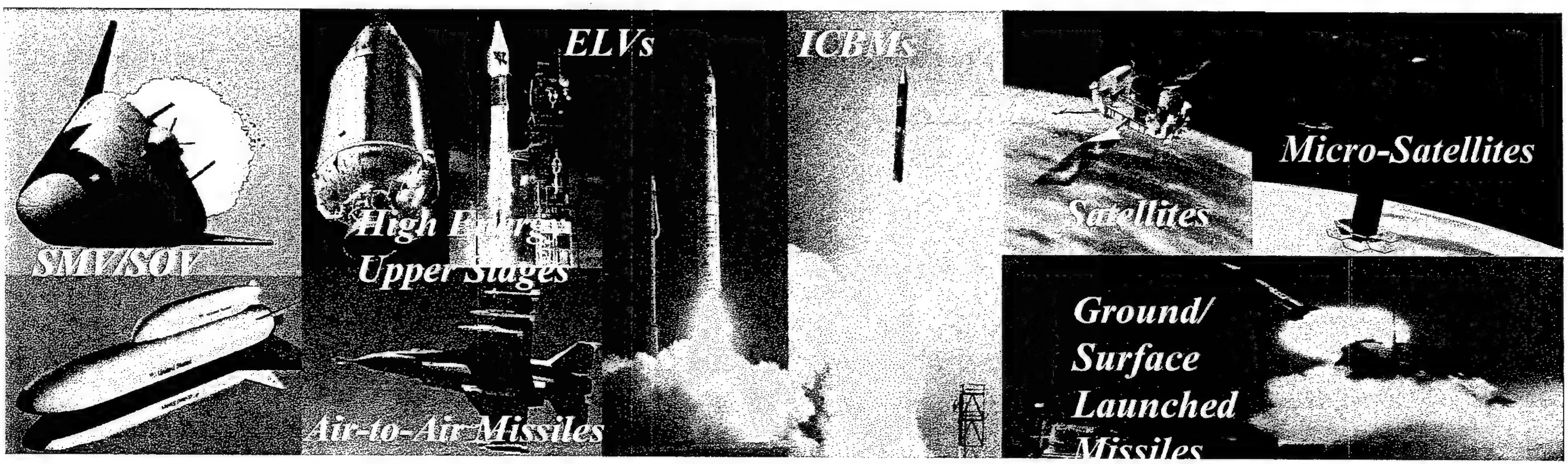
What is IHPRPT?

Integrated High Payoff Rocket Propulsion Technology

The IHPRPT program is a joint government and industry effort focused on developing affordable technologies for, revolutionary, reusable and/or rapid response military global reach capability, sustainable strategic missiles, long life or increased maneuverability spacecraft capability and high performance tactical missile capability.



IHPRPT Program

- A Structured, Government - Industry Program
- Technology Driven, Goal Oriented, Application Focused
- Will Provide Large System Payoffs
- High Return on Investment
- Key Demonstrations Used to Verify Goals

Key Questions To Answer

- What Are You Doing?
- By When?
- Who Cares?
- What Makes You Think You Can Achieve Your Goals?

Goal Generation Constraints

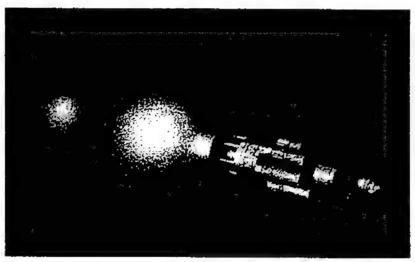
- System Payoffs Must be Significant
- Propulsion Specific Parameters
- Consistent With Projected User Needs
- Achievable

- Goals Must Be Pursued As A Set

The Goals of the IHPRPT Program

BOOST & ORBIT TRANSFER PROPULSION

INCREASE Isp + INCREASE THRUST/WEIGHT OR INCREASE MASS FRACTION + REDUCE FAILURE RATE AND IMPROVE REUSABILITY (MTBR) + REDUCE COST



SPACECRAFT PROPULSION

INCREASE Isp (Bipropellant, Solar Thermal) + IMPROVE MASS FRACTION (Solar Thermal) + IMPROVE $Isp_{(tot)}/Mass_{(wet)}$ (Electrostatic/ Electromagnetic) + IMPROVE DENSITY - Isp (Monopropellant)

TACTICAL PROPULSION

INCREASE DELIVERED ENERGY Isp + INCREASE PROPELLANT MASS FRACTION

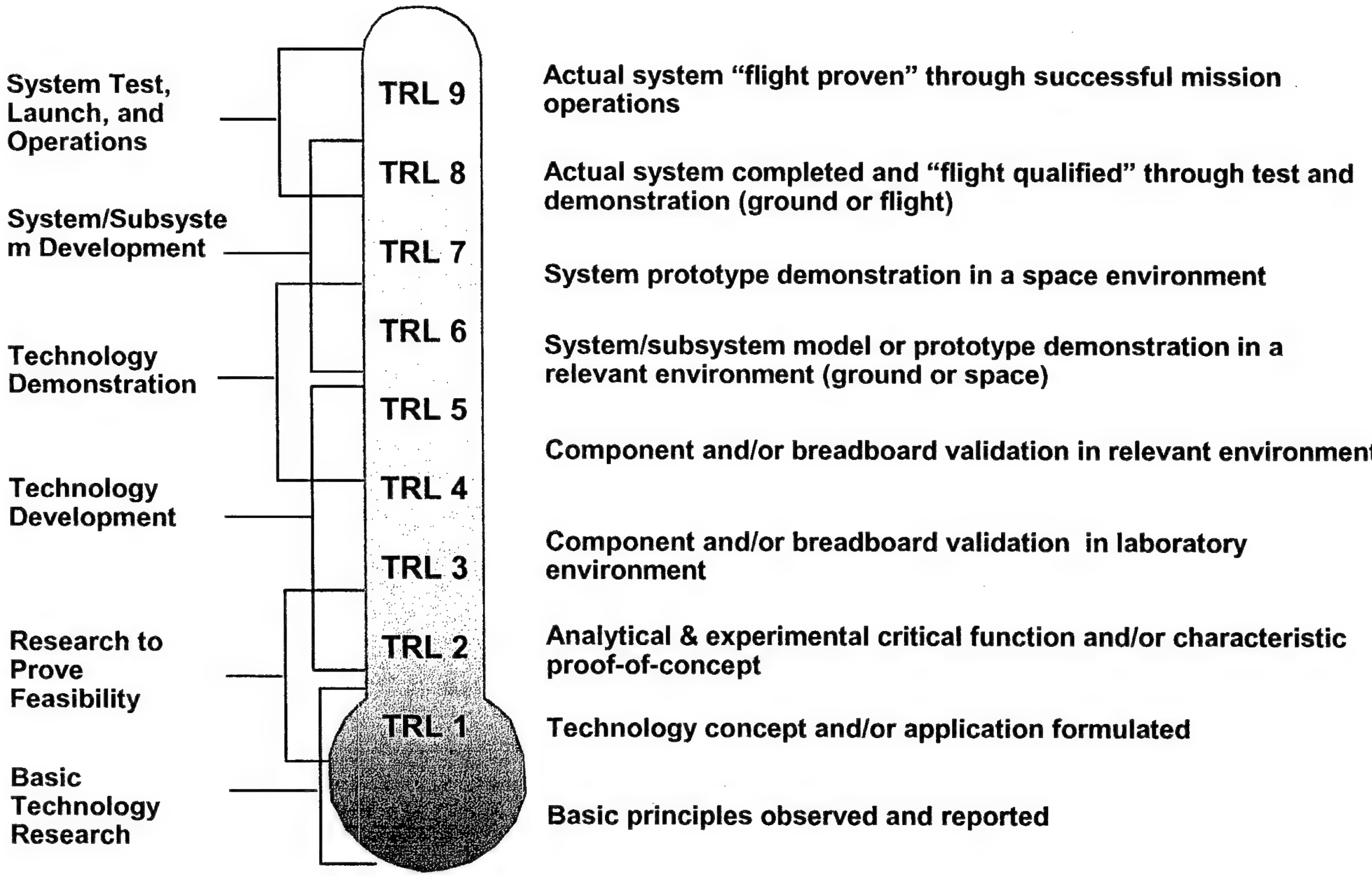
IHPRPT Goals

Boost and Orbit Transfer Propulsion	2000	2005	2010
• Reduce Stage Failure Rate	25%	50%	75%
• Improve Mass Fraction (Solids)	15%	25%	35%
• Improve ISP (sec)	14	21	26
• Reduce Hardware Costs	15%	25%	35%
• Reduce Support Costs	15%	25%	35%
• Improve Thrust to Weight (Liquids)	30%	60%	100%
• Mean Time Between Removal (Mission Life-Reusable)	20	60	100
Spacecraft Propulsion			
• Improve I_{tot}/Mass $_{(wet)}$ (Electrostatic/Electromagnetic)	20%/200%	35%/500%	75%/1250%
• Improve Isp (Bipropellant/Solar Thermal)	5%/10%	10%/15%	20%/20%
• Improve Density-Isp (Monopropellant)	30%	50%	70%
• Improve Mass Fraction (Solar Thermal)	15%	25%	35%
Tactical Propulsion			
• Improve Delivered Energy	3%	7%	15%
• Improve Mass Fraction (Without TVC/Throttling)	2%	5%	10%
• Improve Mass Fraction (With TVC/Throttling)	10%	20%	30%

IHPRPT Structure

- Goals are in Three Phases:
  - Phase I ends 2000
  - Phase II ends 2005
  - Phase III ends 2010
- All Phases Worked Simultaneously:
  - Currently, 6.3 Focused on Phase I Goals
    6.2 Focused on Phase II Goals (some Phase I & II)
    6.1 Contributes to Phase III Goals
- Technology is Mature Enough at the end of Each Phase to Incorporate it into a Milestone I for a New System or an Upgrade to an Existing System

Technology Readiness Level (TRL) Definitions



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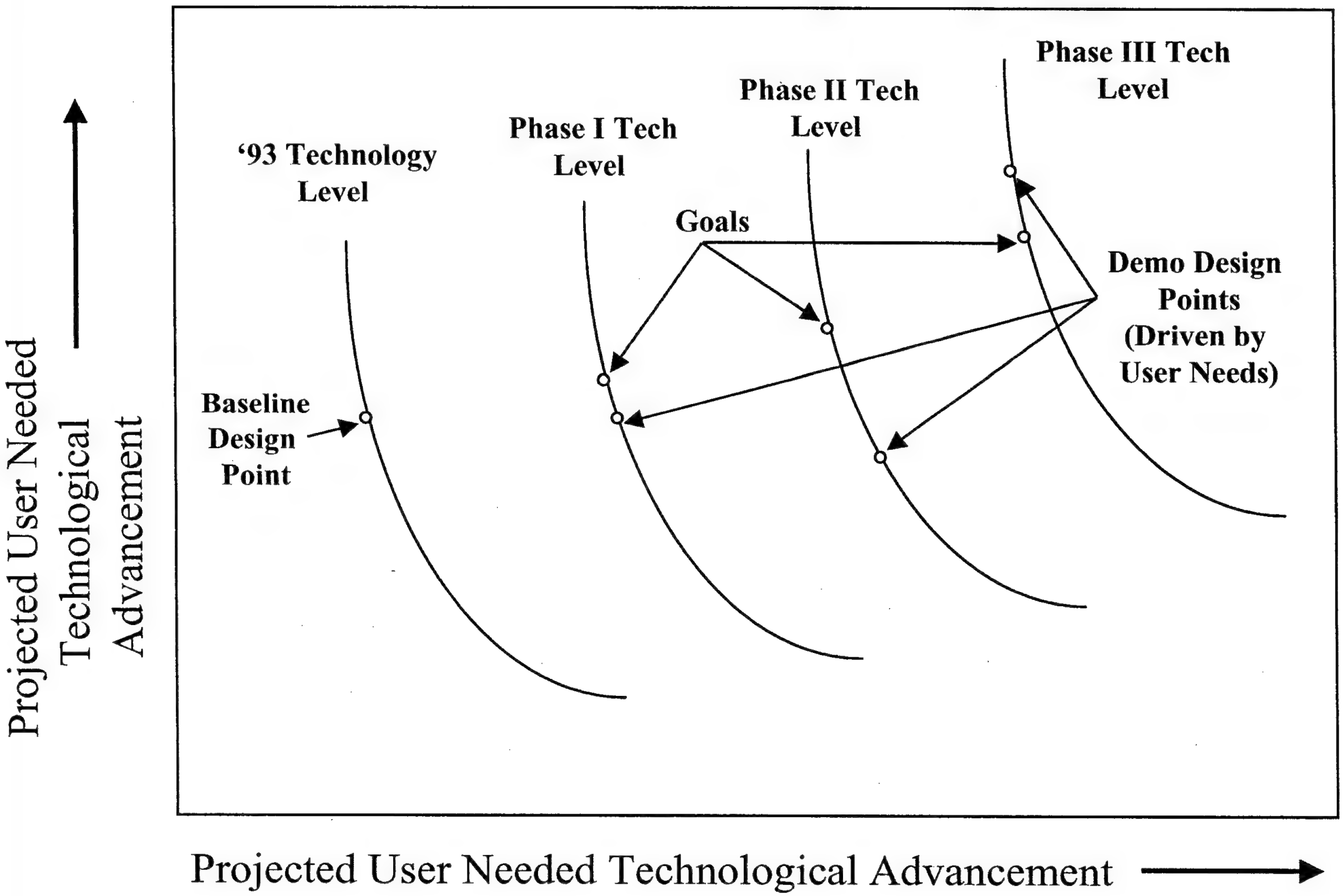
IHPRPT Goal Achievement vs Demonstration Design Point Flexibility



Example

IHPRPT Boost, Orbit Transfer Spacecraft Payoffs

	2000	2005	2010
Boost and Orbit Transfer (Both)			
• Payload	+9% (ELV)/50% (RLV)	+16%/+79%	+22%/+95%
• Cost (Launch/O&S)	-18% (ELV)/53% (RLV)	-26%/-72%	-33%/-82%
Spacecraft (Either/or)			
• Satellite Life (GEO)	+25%($50M Savings)	+35% ($130M)	+45% ($240M)
• Satellite Payload	+10%	+20%	+30%
• Satellite Repositioning	+200%	+400%	+500%

IHPRPT Process

Goal Development
Govt + Industry
(Projected Needs)

DTO Objectives

Future Military Mission Plans

AF TPIPTs
NASA Strategic Plans
Navy FNCs
Army STOs

Goals
Objectives
Tech Challenges
Approaches
(GOTCHa)

Technology Objective
-Component Development-

IHPRPT
Government Plan
(GRPP & IMWG)

Demonstration
-engine/motor-
-major subassembly-

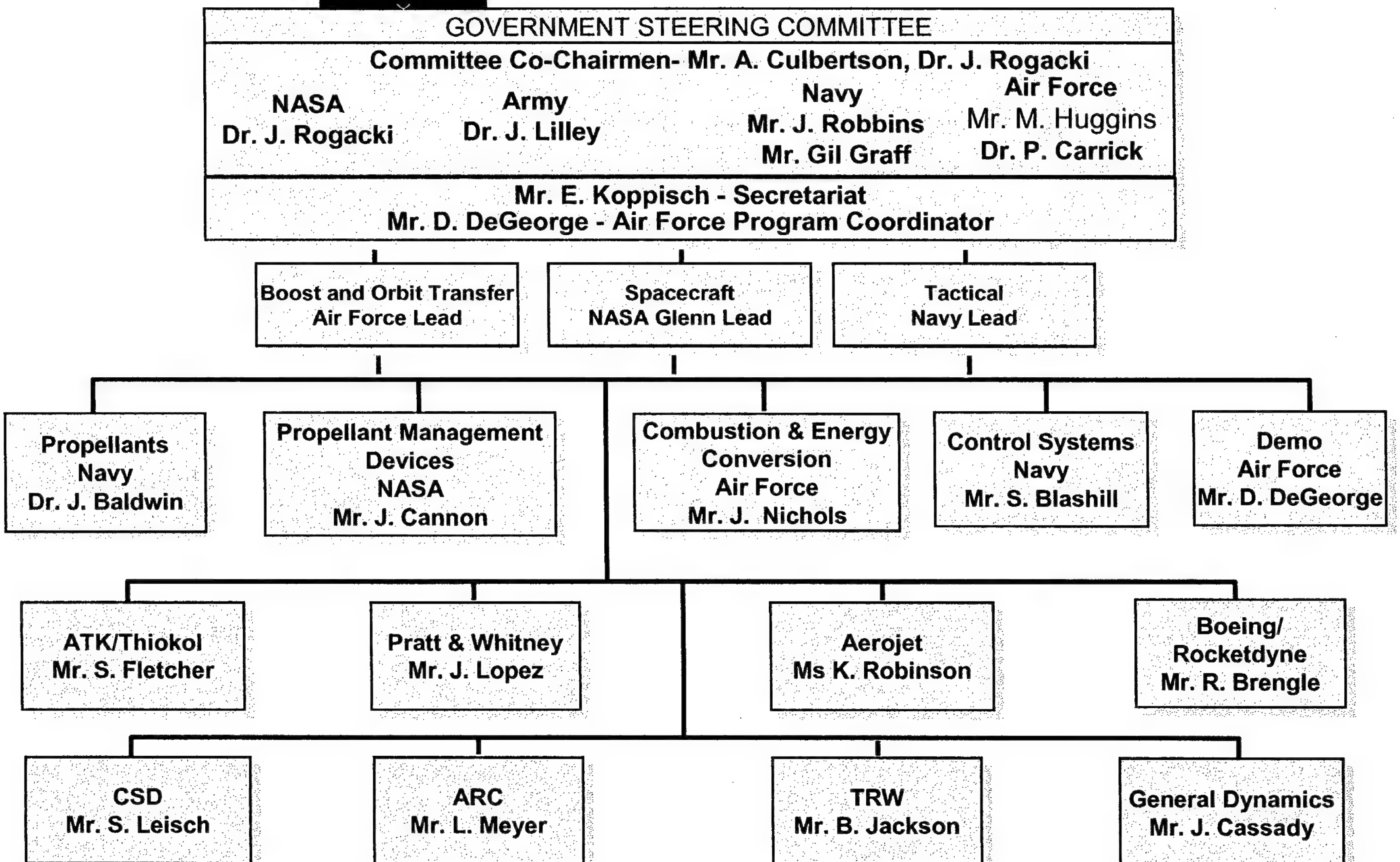
Industry Advanced Rocket Propulsion Plans (ARPP)

Technology Available to User Community

IHPRPT Management Approach

- Fully Coordinated But Not Joint
  - Each Service/Agency Responsible for its Own Efforts and Funding
- Controlling Documents
  - ARPP's
  - GRPP
- Steering Committee to Provide Oversight

IHPRPT Team Organization



Conclusion

- IHPRPT Offers an Outstanding Collaboration Between Government and Industry
  - Prioritizes Development Efforts
- IHPRPT Applicable to New and Existing Systems
  - Time-Phasing Provides Demonstrated Technology When Needed with Interim Technology Off-Ramp
- The IHPRPT Tactical Program Is Progressing Well
  - Innovative High Payoff Approaches Being Pursued With
    - Propellants
    - Case and Insulation
    - Nozzles
    - Thrust Vecor/Magnitude Control

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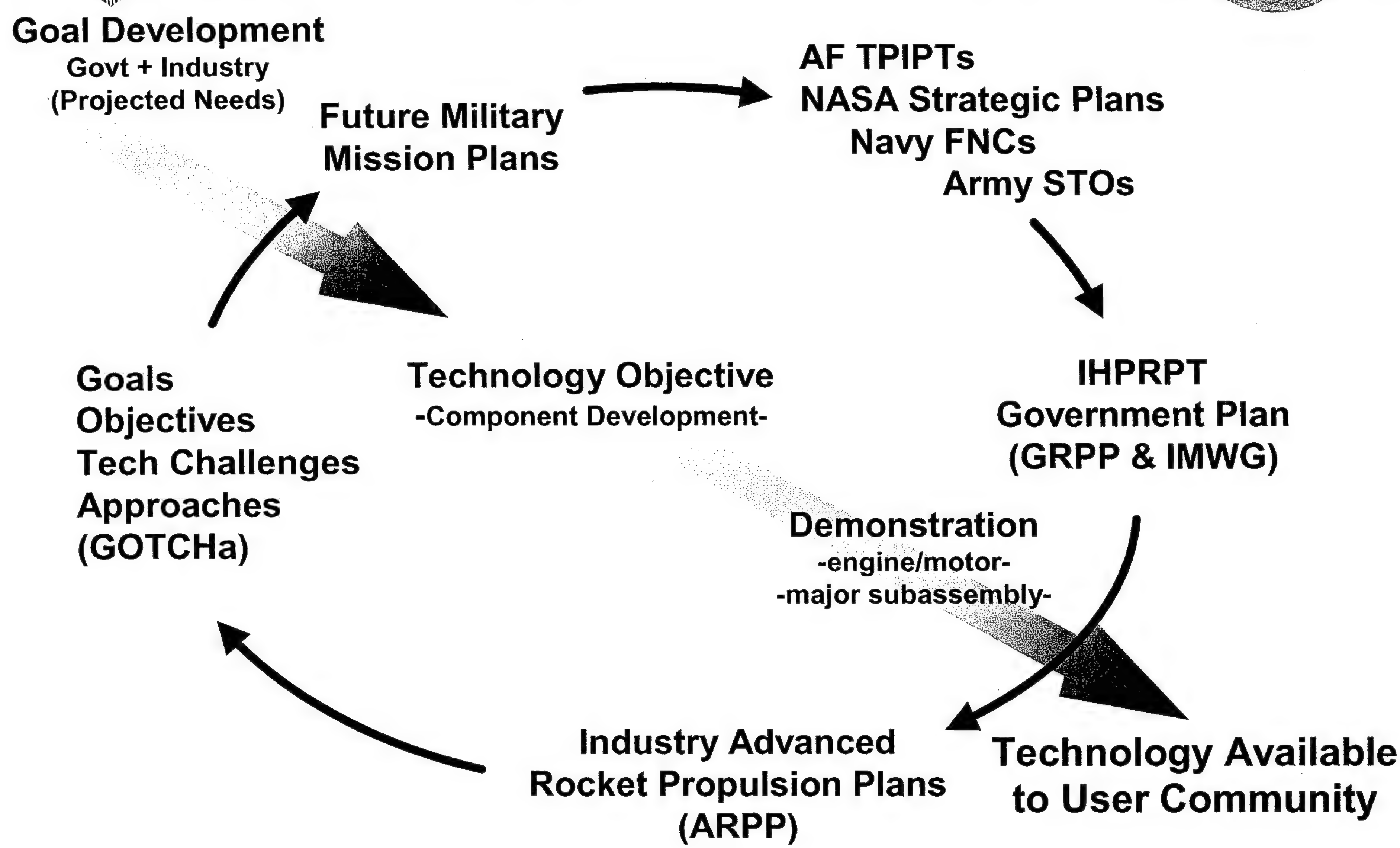
IHPRPT Process



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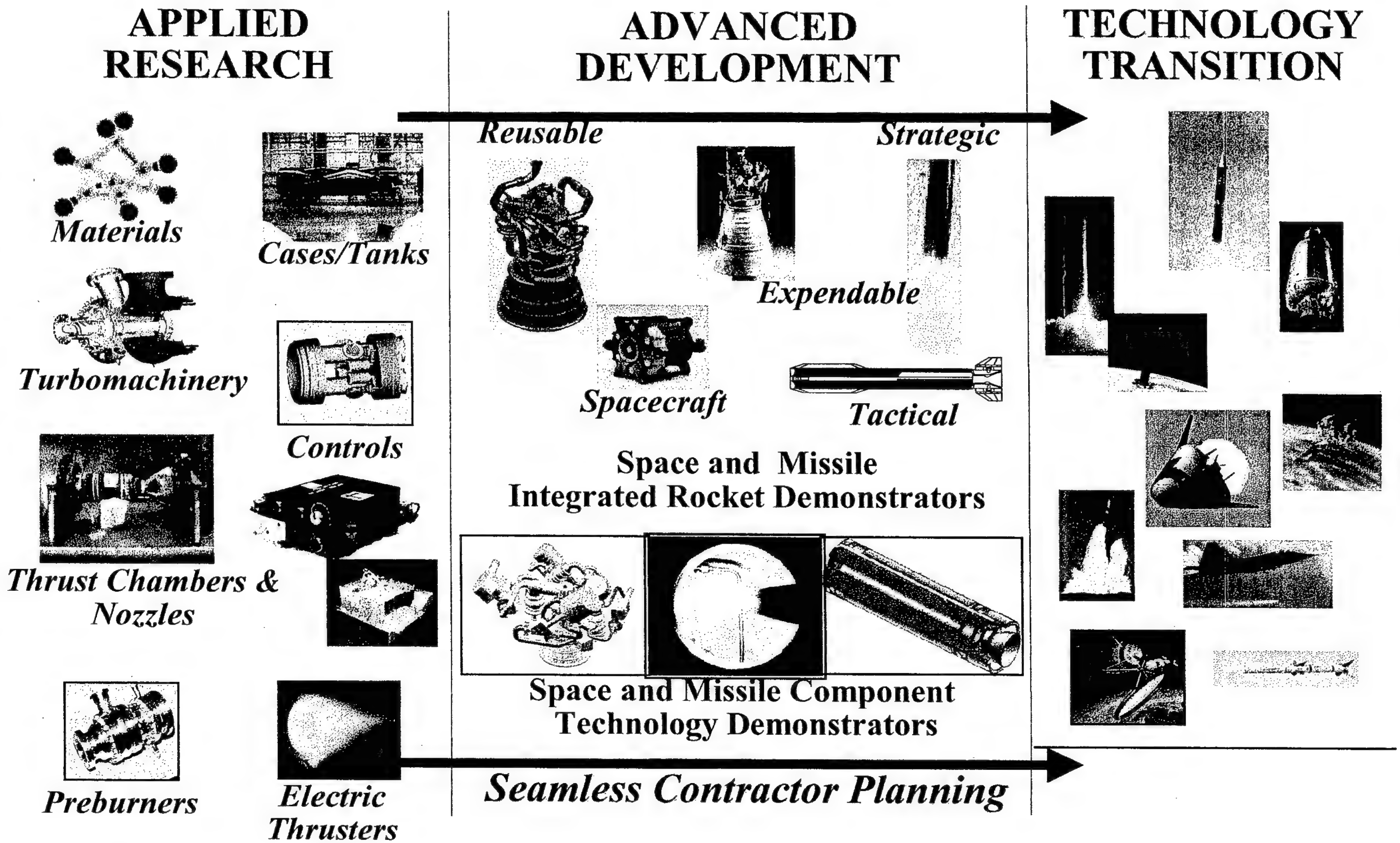
IHPRPT
Building Block Approach



IHPRPT Technology Objectives

- Guide Individual Technology Projects
- Quantifiable Propulsion Characteristics
- Address Specific Scientific/Technology Challenges
- Require New Knowledge or Techniques
- Represent "Mean" Targets
  - Allows Different Approaches to Achieve Objective

- Collectively, They Result in Achievement of the Goals

IHPRPT Advanced Rocket Propulsion Plan (ARPP)

- Plan to Meet Time-Phased Goals
  - Not Required to Work All Three Application Areas
  - Must Work All Goals in Any Area(s) Being Worked
- Describes:
  - Baseline to be Improved
  - Demonstrators
  - Projects in Tech Base
  - Technical Challenges to be Overcome
- Contains:
  - Roadmaps/Milestones/Required Funds
  - Critical Path Analysis
  - Identification of Transition Targets
  - Payoff Analysis
  - Collaboration or Teaming Requirements

IHPRPT
Tactical Propulsion

IHPRPT Tactical Propulsion Goals

PERFORMANCE	2000	2005	2010
Increased Delivered Energy	+3%	+7%	+15%
• Smoke			
• Reduced Smoke			
• Minimum Smoke			
Increased Mass Fraction			
• Motor without TVC/TMC	+2%	+5%	+10%
• Motor with TVC/TMC	+10%	+20%	+30%

SAFETY

Meet Safety Requirements as Performance Goals are Met

COST

No Increase in Cost as Performance Goals Are Met

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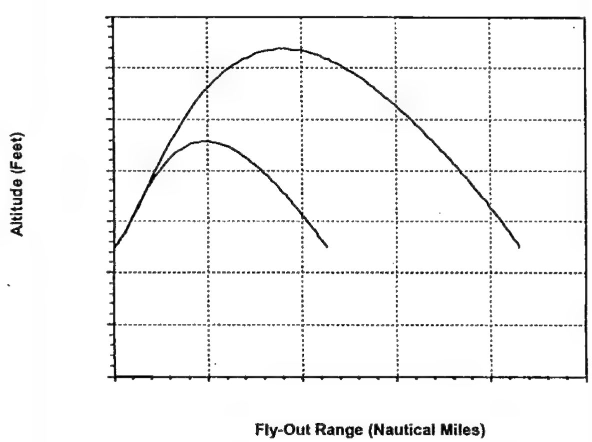
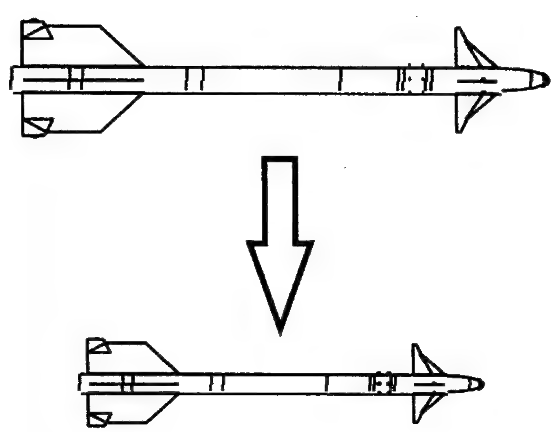
What is IHPRPT for Tactical ?

- *Tactical Propulsion Goals Focus On Performance*
  - *•Delivered Energy*
  - *•Mass Fraction*
- *Tactical Propulsion Contraints Include;*
  - *•Cost When Brought Forward to Production*
  - *•IM Compliance*

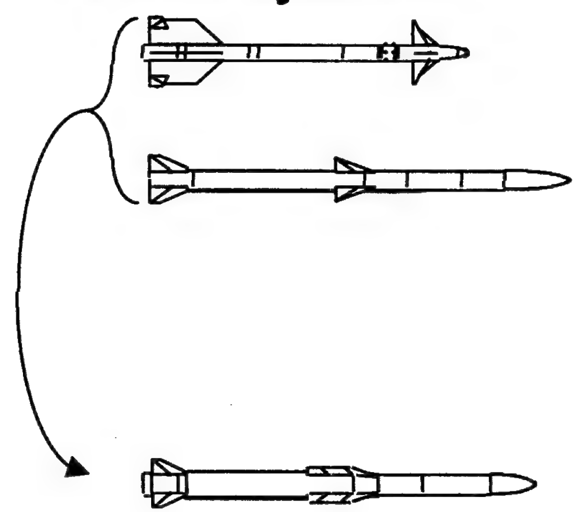
Increased Weapon Kinematics



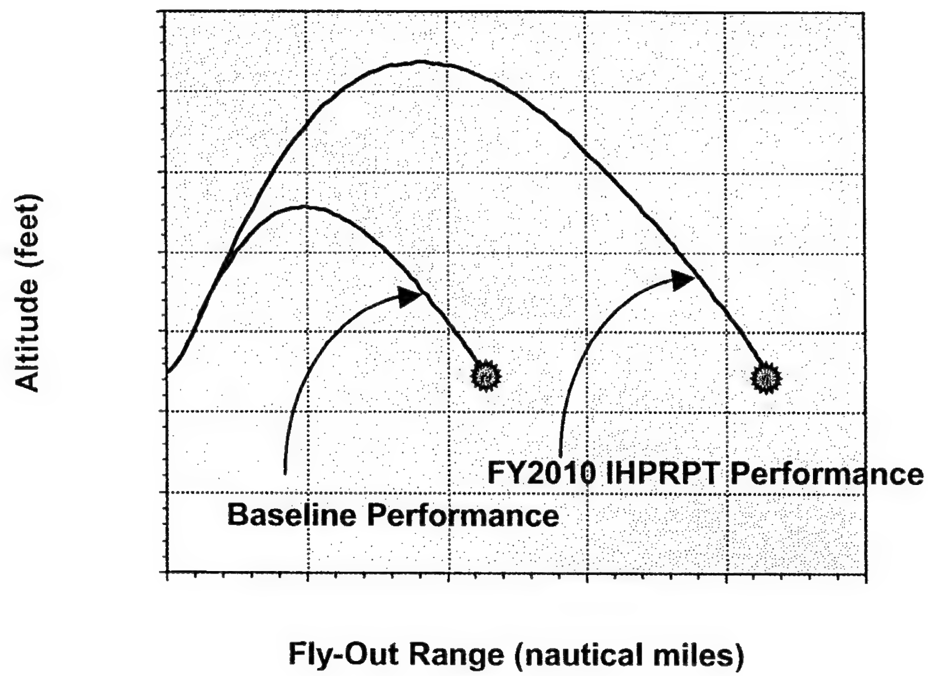
Decreased Weapon Size



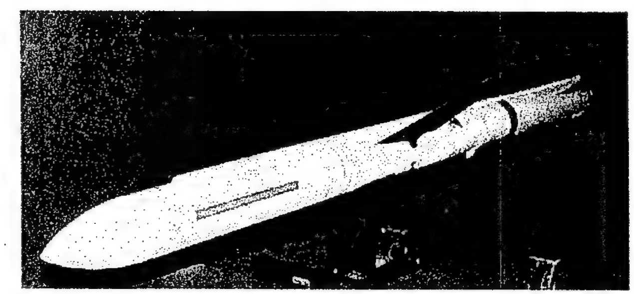
Potentially Fewer Systems



Example IHPRPT Payoff Analysis Results



Typical Air-Launched System



Paramaters Considered:
Launch Weight
Length
Diameter
Warhead Weight
Propellant Weight
S.L. Delivered Isp
Total Impulse

- 82% Increase in Launch Range
- 16% Decrease in Time-of-Flight
- 58% Increase in Terminal Maneuverability
- 28% Increase in Average Velocity

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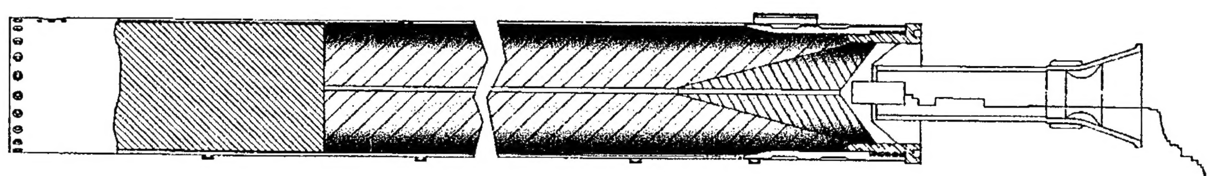
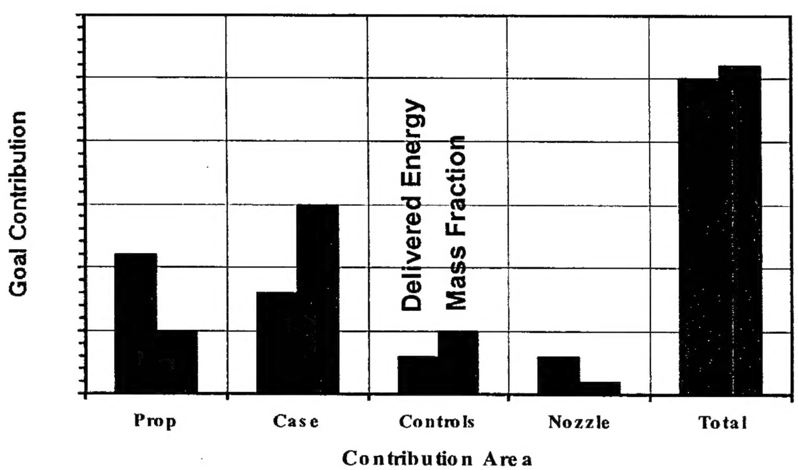
Key Features & Goal Contribution

Advanced Air-to-Air Missile Rocket Demonstrator Phase-II

Propellant	Propellant Mgt Devices	Control Systems	Comb & Energy Conv
• Highly Loaded RS Propellant	• High Press Composite Case	• Dual Movable Nozzle TVC	• Low/No Erosion Nozzle



Component Contributions to Goals



Critical Technologies/Technical Challenges

- *High Burn-Rate Reduced Smoke Propellants*
- *Highly Loaded Grain Designs with Adequate Thrust*
- *High Pressure, Stable Motor Operation*
- *High Pressure, Strength, & Stiffness Composite Cases that Satisfy Air-Launch Requirements*
- *Low/No Erosion Nozzle Materials for Reduced Smoke Propellants at High Pressure Operation*

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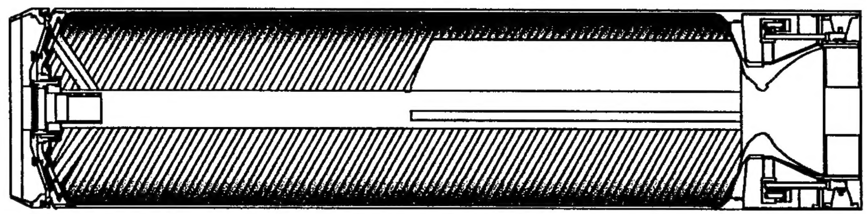
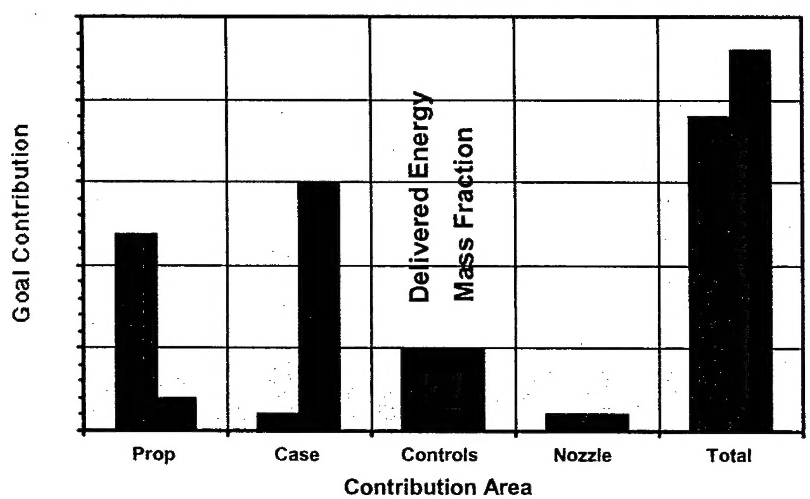
Key Features & Goal Contribution

Surface-Launch Demonstrator for Phase-II

Propellant	Propellant Mgt Devices	Control Systems	Comb & Energy Conv
• Highly Energy Alum Prop	• Comp Case & Adv Insulation	• On-Command Pintle	• Low/No Erosion Nozzle



Component Contributions to Goals



Critical Technologies/Technical Challenges

- *High Energy/Density Aluminized Propellants that are IM Compliant*
- *Highly Loaded Grain Designs with Achievable Burn-Rate Propellants*
- *High Pressure, Strength, & Stiffness Composite Case for Surface-Launch Applications*
- *TVC/TMC in Volumetrically Efficient Package*

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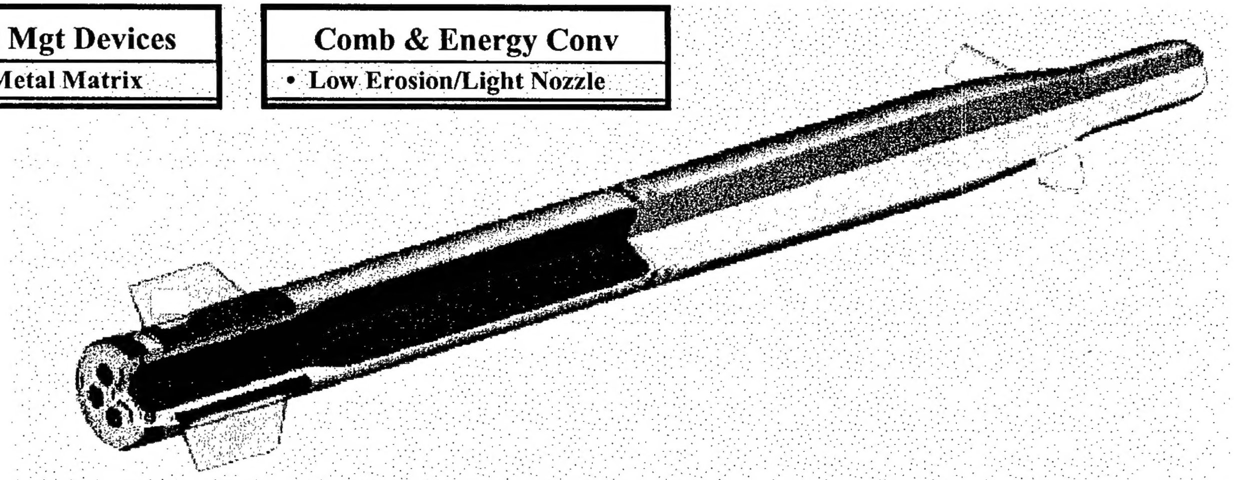
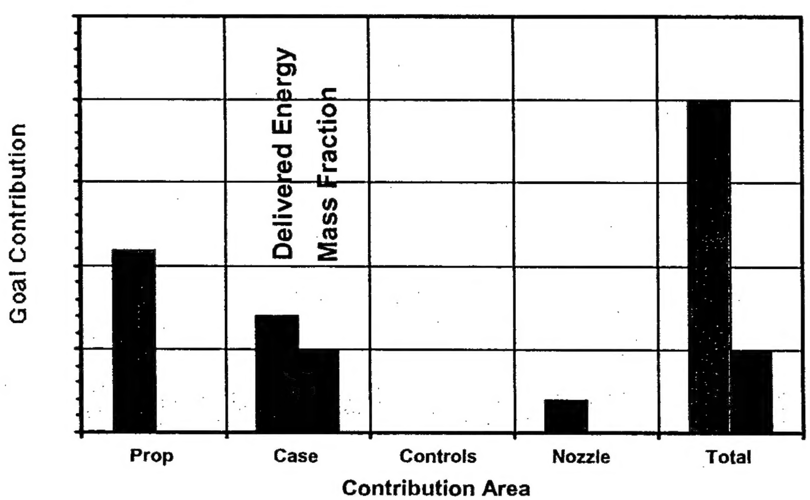
Key Features & Goal Contribution

Gun-Launch Demonstrator for Phase-II

Propellant	Propellant Mgt Devices	Comb & Energy Conv
• High Press Alum Propellant	• High Press/Metal Matrix	• Low Erosion/Light Nozzle



Component Contributions to Goals



Critical Technologies/Technical Challenges

- *Aluminized Propellant with no Slope Break*
- *High Pressure Motor Operation*
- *High Pressure, Strength, & Stiffness Composite Case for Gun-Launch Applications*
- *Light Weight/No Erosion Nozzle Materials*

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